Solar Thermal Energy for Sustainable Development in Tunisia

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Solar Thermal Energy for Sustainable Development in Tunisia: the case of the PROSOL Project

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Abstract: The massive increase in production and consumption of fossil fuels during the 20th century was accompanied by several problems in economic, social and environmental levels. Thus, the energy as it is produced, distributed and consumed currently does not meet the requirements of sustainable development. Hence it is necessary to use RE that do not emit GHG in order to move toward the sustainable development. Since mid-1980s, Tunisia has implemented its national strategy in the field of RE. To revive the market of solar water heating, the government decided to establish, in 2005, an ambitious program called PROSOL. With the help of case study (PROSOL project), the paper shows that the contribution of RE to the economic, social and environmental dimensions of sustainable development is significant.

Keywords: sustainable development; renewable energy sources; PROSOL project.

1. Introduction

The intensive use of energy has caused harmful effects to the environment, the most dangerous and most global of them is the climate change [1,2]. Indeed, the energy consumed in the world is largely based on fossil fuels (oil, natural gas and coal) which emit Green House Gas (GHG), including carbon dioxide, which are responsible of global warming [3,4].

The phenomenon of global warming has received more attention, especially with the emergence of the concept of sustainable development since the late 80s. It is clear that climate change and its disastrous consequences are an obstacle to the achievement of sustainable development. Thus the current energy system based on fossil resources is incompatible with the achievement of sustainable development objectives [5]. Faced with this situation, the use of Renewable Energies (RE) is no longer a choice but a necessity.

Tunisia is one of the few developing countries which have granted, since the mid-80s, a great importance to the use of RE as an essential part of its policy of energy conservation. The solar energy is considered as a promising source in Tunisia which can contribute to the improvement of the energy balance and the environmental protection. In fact, it is proved that Tunisia is endowed with good solar energy potentials. To revive the market for Solar Water Heaters (SWH), the government decided to establish, in 2005, an ambitious project called PROSOL (Programme Solaire) which has many environmental and socioeconomic benefits.

The main aim of this paper is to analyze in depth the Tunisian experience in SWH promotion with a focus on the PROSOL project. In fact we give a detailed analysis of all features of this project and also its socio-economic and environmental impacts such as the development of a local industry, employment creation, CO2 emissions reduction and energy saving.

This paper begins with an exposition of the concept of sustainable development and its main approaches. After this exposition, a review of the literature of the contribution of RE to sustainability is provided. Then, the structures of PROSOL Project as well as his impacts are reported and finally we conclude.

2. Theory

2.1. The concept of sustainable development

Sustainable development can be introduced as a process or evolution since it is an economic development which allows protection of the environment and respect for social justice (between generations and within the same generation). Contrary to what is often believed, sustainable development is not limited to environmental awareness, but rather it aims to establish a better balance between the economic, social and environmental dimensions.
The most known and cited definition of the sustainable development was given by the Bruntland report p.8, in 1987: "… *it meets the needs of the present without compromising the ability of future generations to meet their own needs*" [6].

Since this widely known report, a variety of definitions of sustainable development and sustainability has appeared in the literature [7,8,9,10]. A recent definition is given by Glavic and Lukman [9], p. 1884:"*Sustainable development emphasizes the evolution of human society from the responsible economic point of view, in accordance with environmental and natural processes*."

Since the popularization of the term sustainable development by the World Commission on Environment and Development in 1987, this concept has become the concern of scientists from different fields [see, among others, 11,12,13,14], of international organizations such as the World Bank [15,16] and the Organization for Economic Cooperation and Development (OECD) [17,18,19,20] and of many international conferences (United Nations Conference on Environment and Development in 1992, the World Summit on Sustainable Development in 2002 and the United Nations Conference on Sustainable Development in 2012).
Literature that addresses this concept is increasing constantly [21,22,23,24,25, 26,27,28,29,30,31,32,33]. Even that the literature and the international agreements treating the concept of sustainable development are abundant, this concept still contested, ambiguous and multi-faceted [11,34,35,36,14]. So there is a great challenge to give this concept at the same time a consistent and operational content. Osofsky [14] tried to explain the reasons of the conceptual ambiguity of this term.

It needs to be stressed that there is no yet a unique universally acceptable definition of sustainable development [29,33] but at least there is a wide consensus that the main elements of sustainable development are: environmental, social and economic sustainability [37,38].

The objective of sustainable development is therefore to reconcile economic efficiency, social progress and the preservation of the ecosystem. So, a sustainable development strategy consists in managing the necessary compromise between these three dimensions. Therefore, the political and institutional dimensions are also central. There are many interpretations of the interrelations between these three ingredients (for more details see Mauerhofer [31]). For example, Munasinghe [38] represents the sustainable development using a triangle (see Fig.1).

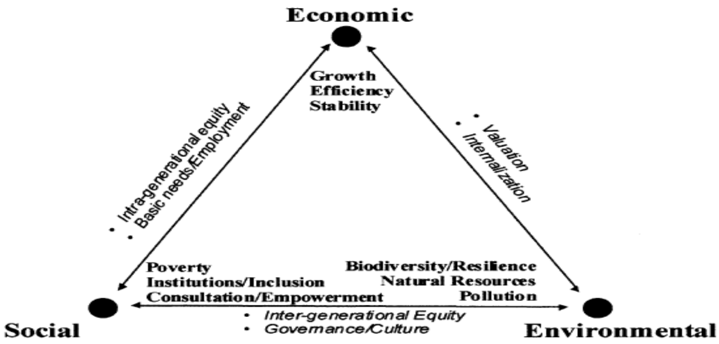

Fig.1.Elements of sustainable development

Source: Réf [38]

This figural concept is commonly used but is also criticized of indicating equity between the three dimensions of sustainable development and falling to show clearly the interrelations [31].

There are basically two main approaches of sustainable development: strong sustainability and weak sustainability. The main difference between those approaches is concerning the substitutability among environmental assets and man-made capital [39].

The weak sustainability, which is held by neoclassical economists, advocates the substitutability between natural capital and man-made capital. It is based on the work of Solow [40]. In fact, according to neoclassical economists, sustainability is defined as no decay over time of the overall welfare of society. So, the capital stock must remain intact from one generation to another, in order to maintain a welfare of future generations which has to be at least equal to that of present generations [11,41,42,43,44,45].

Thus, the reduction of natural capital (e.g. the use of an exhaustible resource) may be offset by an increase in manufactured capital of the same value, which will remain constant capital stock and thus the possibility of creating in the future at least as many goods and services. So there is an exchange that takes place in time: the present generation consumes natural capital, but in return bequeaths to future generations more production capacity in the form of stocks of equipment, knowledge and skills.

Hartwick [46] suggested the investment policy that would achieve sustainability. In fact, Hartwick's rule is a proposal to invest rents from the exhaustible resources used at each date in the accumulation of produced capital goods. According to this rule, net investments are zero at each point in time, and then utility is constant.

Proponents of ecological economics support the idea of strong sustainability. The strong sustainability paradigm owes a great deal to the pioneering work of Daly [47,27]. This approach is based on the assumption of complementarity between natural capital and man-made capital [39]. Thus, it is necessary to maintain, over time, a stock of "critical natural capital" that is essential for the well being of future generations [48,49,26,50]. In fact, some environmental components are unique and services provided by them cannot be replaced by man-made capital.

Nowadays, the term sustainability is associated with all the concerns of the modern life. In fact, we speak about social sustainability, financial sustainability, sustainable jobs, sustainable cities, sustainable societies, etc. So that Daly [27], p.9 writes in his famous book "Beyond Growth, The Economics of Sustainable Development": "*We expected any day to hear about "sustainable sustainability'*"".

2.2. The contribution of RE to sustainability: a brief overview of the literature

2.2.1. The literature on the contribution of RE to reduction of GHG emissions

It's widely known that global climate change is mainly due to CO2 emissions which are caused especially by conventional energy. According to UN/DESA [51], energy is essential to economic development and renewable energy is essential to a future without dangerous climate change. So, a rapid conversion from fossil fuels to RE is no more a choice but a matter of urgency to attempt the climate stability. There is a common consensus between academic scientists that RE use is necessary to mitigate climate change. The studies in this field are multiple and varied. Existing literature has focused on the ability of RE to reduce GHG emissions [52,53,54,55,56,57,58,59]. This environmental benefit becomes more interesting, especially, with the global awareness of the dangerousness of climate change.

Mathews [60] considers that the use of RE is needed in order to reduce carbon emissions. Dincer [61] claims that there is a deep connection between the use of RE and the sustainable development. In fact, RE are one of the most effective solutions to actual environmental problems. Dincer [61] presents a detailed analysis of environmental impacts of a massive use of fossil fuels. The most dangerous are: acid rain, deterioration of the ozone layer and the greenhouse effect. Potential solutions are identified for these problems such as the use of renewable energies. The relationship between RE and sustainable development is analyzed from a practical case for the city of Saarbrucken in Germany which had implemented in 1980, an energy program that won "the local government honor" at the Rio conference in 1992.

Dincer and Rosen [1] argue that there is a strong connection between energy, environment and sustainable development. They consider that a society that aims to achieve sustainable development must use RE with no negative impacts on the environment. Kalogirou [62] presented in his article « Environmental benefits of domestic solar energy systems », environmental problems caused by the use of fossil fuels and the need to use solar energy as it has little negative impact on the environment. According to his study, the use of solar energy to heat buildings and to heat water can prevent large quantities of GHG. Indeed, Kalogirou [62] requires that GHG reduction is the major advantage of using solar energy and he adds that solar energy systems should be employed whenever possible to achieve a sustainable development, using the slogan "think globally- act locally".
While some studies are general, other studies focus on specific regions and/or specific RE, in order to determine their impact on climate change mitigation. Several papers focus on developing countries especially those which have significant potential for RE. For example, Bilen et al. [63] discuss the necessity of using RE in Turkey to reduce GHG emissions and therefore participate to the limitation of the magnitude and extent of climate change, especially that Turkey has a geographical location that promotes the use of renewables. Many other papers treat the case of Turkey [see, among others, 64,56,65].

Yu and Qu [66] treat the case of China which is the world's largest carbon dioxide emitter. Their analysis suggests that wind and solar energy can be used as efficient tools in order to reduce carbon dioxide emissions and then mitigate the most globally concerned environmental issue which is climate change.

There are also many empirical studies treating this issue, we will just focus on some recent ones. Amponsah et al. [67] present a comprehensive review of literature concerning the Life Cycle Assessment (LCA) of GHG emissions from RE (79 studies are reviewed). Results show clearly that life cycle GHG emissions in conventional sources are higher than those in renewable sources. They found also that off shore wind technologies are sources of the lowest GHG emissions.

Sapkota et al. [68] examine the impacts of the use of some RE (such as biogas, improved cooking stoves, micro hydro and solar power) in rural communities in Nepal. This study uses the Long-range Energy Alternatives Planning (LEAP) model. The results of this model show that the implementation of micro hydro for the next 20 years will reduce CO2 emissions by 2.553 million tons (Mt). Concerning the use of solar power, biogas and improved cooking stoves, it will permit a significant reduction in CO2 emissions of 5.214 Mt, 35.880 Mt and 7.452 Mt, respectively.

Shafiei and Salim [69] try to explore the causes of CO2 emissions. They use a STIRPAT model based on data from OECD countries (from 1980 to 2011). The empirical results show that renewable energy consumption decreases CO2 emissions whereas conventional energy consumption increases CO2 emissions. Yadoo and Cruickshank [70] used sustainability indicators in order to explore the role of renewable energy mini-grids (in Nepal, Peru and Kenya) in climate change mitigation and poverty reduction.

Granovskii et al. [71] argue that the introduction of wind and solar energy instead of natural gas to produce electricity and hydrogen leads to a reduction in polluting emissions. With present costs of wind and solar electricity, it is shown that, when electricity from renewable sources replaces electricity from natural gas, the cost of air pollution emission abatement is more than ten times less than the cost if hydrogen from renewable sources replaces hydrogen produced from natural gas.

Creutzig et al. [72] are interested in the European geographical periphery. They consider that the transition to a RE system can mitigate at the same time the climate change and the Eurozone crisis. In order to foster the renewable energy transition, they suggest, in addition to country-specific policy frameworks, a wide coordination between member state policies.

So the use of RE is not just a path to climate change mitigation but it is also a way to realize socio-economic advantages which will be detailed in the two following sections.

2.2.2. The literature on the contribution of RE deployment to socioeconomic sustainability

In what follows, we will mention, first, the literature that has focused on the impacts of renewable energy on both economic and social dimensions of sustainable development and then we will focus on studies that have analyzed the renewable energy contribution to job creation.

According to Kammen et al. [73], the greater use of renewable energy systems provides economic benefits through innovation and new job creation. Goldemberg [2] believes that RE are a key factor to achieve sustainability. Indeed, if the global energy system will continue to be dominated by fossil fuels the environmental problems at regional and global levels, the dependence on energy imports and the supply problems will persist. The author proposes as a solution to those problems the increase of the share of RE in global energy system by using top down policies (the Kyoto Protocol) and bottom-up policies (Renewable Portfolio Standards).

Mathiesen et al. [74] presented the analyses and results of the design of a 100% renewable energy system, in Denmark, by the year 2050. The results of the energy system analysis model EnergyPLAN show that 100% renewable energy systems will be technically possible in the future, and may even have positive technological and socio-economic results.

Sáenz de Miera et al. [75] analyzed the impact of renewable electricity support schemes on power prices. They analyzed empirically the case study of Spanish wind generation. The results show that there is a negative correlation between the promotion of wind electricity and the wholesale market price.

To determine the impact of renewable energy deployment on socio-economic sustainability, we have to emphasize the impact of RE on socioeconomic indicators such as investment, general price level in the country, wages, energy prices and Gross Domestic Product (GDP). However, most of the existing studies have just focused on one indicator which is GDP.

The existing literature interested in the relationship between RE and GDP is rich and various. Chien and Hu [76] used a structural equation modeling in order to analyze the effect of RE on GDP. The results showed that there is a positive relationship between RE and GDP (through increasing capital formation).

Chien and Hu [77] analyzed the effects of the use of renewable energies on the technical efficiency of 45 economies between 2001 and 2002, using Data Envelopment Analysis model. In this model, labor, capital stock and energy consumption are the three inputs and real GDP is the single output. The results of this paper are: increasing the use of RE improves the economy's technical efficiency, conversely, increasing the input of traditional energy decreases technical efficiency.

The investigation of the renewable energy consumption–GDP relationship has been widely covered by different empirical studies that analyze different countries and regions. Most empirical studies found that there is long run causal relationship between RE consumption and GDP [see, among others, 78,79,80,81,82,83].

Other studies focused on the relationship between RE production and GDP. For example, Abanda et al. [84] used statistical analytic techniques to determine the correlation between RE production and economic growth. They analyzed many blocks of the African continent. They found that there is a positive correlation between RE production and GDP except in the southern Africa Block in which this correlation is negative.

2.2.3. The literature on the impact of renewable energy deployment on employment creation

Since the economic crisis, many international organizations, have advocated the need for the expansion of RE investment, both in developed and emerging countries in order to boost the economy, create jobs and mitigate the climate change. So, according to many reports [85,86,87,88], the economic crisis is an opportunity to move toward a green path. Therefore, we assist to the emergence of the Green Economy Initiative of UNEP [88] and the Green Growth Strategy of OECD [89,90]. The expansion of the RE sector is an essential component of those strategies.

According to the report of UNEP et al. [91], the technology which offers the highest employment generation is solar photovoltaic (PV) with 7 to 11 jobs per Megawatt (MW) of average capacity. This report indicated that, the number of jobs in the PV sector would rise from 170,000 in 2006 to 6.3 million in 2030 and the global employment in the wind energy sector would grow from 300,000 in 2006 to 2.1 million in 2030.

According to UNEP et al. [92], the overall employment in wind and solar will grow from 1.2 million in 2011 to two million in 2020. In fact, in 2011, the onshore wind sector and its sub-contractors employed 488,000 people, while the PV sector employed 675,000. The offshore wind sector and solar thermal employed respectively 29,000 and 41,000.

According to Pollin et al. [93], solar generation is more labor intensive than traditional generation. In fact, the solar energy allows the creation of 5.4 direct jobs per million dollars of output, whilst coal generation only creates 1.9 direct jobs and oil and gas creates only 0.8 direct jobs.

Wei et al. [94] also focus on the solar energy sector and they found that, compared to traditional generation, solar PV creates more jobs. Even when compared to other renewable resources, solar PV sector is more labor intensive.
Many studies deal with the potential of creating green jobs in the European Union [95,96]. This is due essentially to its ambitious targets of attending 20% of its energy from renewable sources by 2020. For example, Blanco and Rodrigues [95] give an estimation of direct wind energy employment in all European Union countries.

In Europe, Germany and Spain have received the most interest from researchers due to their ambitious strategies and achievements in the field of renewable energies. Several studies [97,98,99,100] treat the case of Germany and aim to determine the effect of the renewable energy promotion on the employment creation and on all the economy.

There are also many studies which take an interest in the Spanish case [see, among others, 101,102,103]. Those studies deal with the positive impacts on employment of RE expansion. But there are also studies which criticize the Spain policy for the promotion of RE and try to present a critical analysis to the Spanish experience such as Alvarez et al. [104]. In fact in this paper, the authors try to response to the question: at what price? The authors show that the ambitious Spanish strategy came at great financial cost (public aid, subsidies and direct investment grants) as well as costs in terms of jobs destroyed elsewhere in the economy.

Since the economic crisis, the USA has accorded a great importance to the concepts of green economy and green jobs. So many studies have analyzed the positive impacts of promoting renewable energies in USA, mainly in terms of green jobs creation [105, 94,106]. Other studies criticize the USA strategy of greening the economy and show the negative impacts of the great support to the renewable energy sector [107, 108]. Both of those studies conclude that renewable energy promotion will cost jobs.

Recently the studies on the impact of RE expansion on the job market treat the case of many regions and countries, such as the Middle East [109], Greece [110], Portugal [111], China [112], Denmark [74].
Cai et al. [112] determined that, in 2010, for every one percent increase in the share of solar PV generation, in China, there could be a 0.68% increase in total employment.
Mathiesen et al. [74] presented the analyses and results of the design of a 100% renewable energy system, in Denmark, by the year 2050. The results indicate that putting in place energy savings, renewable energy and more efficient conversion technologies can have positive socio-economic consequences, create new jobs and potentially realize large earnings on exports.

The high level of uncertainty surrounding the green jobs estimates of these studies is due to different factors such as the ambiguity of the concept "green job" and also the use of different models and ratios to estimate job creation [113,114].
Studies analyzing the impact of renewable energy on job market generally use methods which can be classified into two types: analytical methods and Input- Output methods. Lambert and Silva [114] discuss the advantages and disadvantages of those methods. They conclude that analytical studies are more appropriate for regional studies while input-output methods are more convenient to national and international studies.

There are many ways of measuring jobs created in the renewable energy sector such as jobs per annual MW installed, jobs per cumulative MW installed, manufacturing jobs per MW, person-year per MW.
While measuring the number of jobs created is possible using job ratios, determining the quality of jobs created is a delicate issue. Sastresa et al. [103] try to describe the quality of jobs created in the renewable energy sector using a Quality Factor (QF) for each renewable energy technology, in Aragon (Spain). The results of this study show that wind energy generated higher quality jobs than solar thermal and PV.

3. Tunisia: a favorable context to renewable energy promotion

3.1. Energy dependence

Because of the stagnation of the national energy supply and the increase of energy demand, we assist to an increasing dependence on foreign energy.

Until the mid-80's, Tunisia had benefited from a favorable energy situation. During this period, the energy sector had played an important role in the economic growth in Tunisia. Indeed, in 1980, the energy sector presented, approximately 13% of GDP and 16% of national exports [115].

By the late 80's, this favorable situation changed because of the declining production of oil and the rapid increase in national demand for energy products. In 1994, Tunisia recorded, for the first time, a deficit in its energy balance. This situation was resolved

by doubling the Algerian-Italian gas pipeline, in 1995. But from 1999, the energy balance became again in deficit due to the steady rise in energy demand coupled with a stable supply.
The demand for primary energy reached 6,789 Kilo Ton Oil Equivalent (ktoe) in 2002 (excluding biomass), against only 3,000 ktoe in 1980, registering an average annual rate of increase of about 4% per year [115]. According to the strategic study of ANME [115], the conventional primary energy consumption will grow during the next three decades, at an average annual rate of about 4.4% from 6,700 ktoe in 2000 to 24,600 ktoe in 2030.

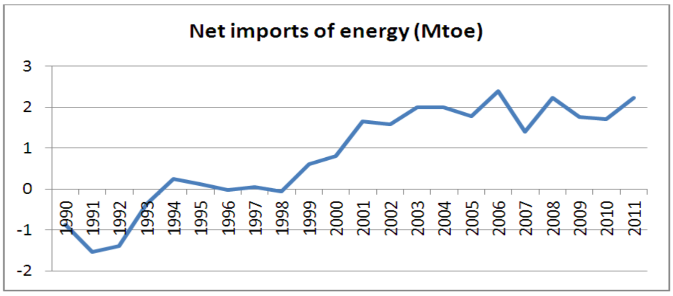

Fig.2. Tunisia's net imports of energy (Mtoe) from 1990 to 2011
Source: data collected from Ref [116]

According to OECD/IEA statistics [116], net imports of energy were just 0.25 Mtoe in 1994. Since 1999, the amount of net imports is increasing steadily and reached 2.23 Mtoe in 2011 (See Fig.2).

Tunisian primary energy supply which was 9,504 Ktoe in 2011 is dominated by natural gas with 45.40%, but oil is also significant at 39.90%. The biomass-energy (essentially used for cooking food in rural areas) and biofuels contribute rather significantly amounting to 14.60% of the total primary energy supply. Finally, renewable energies (geothermal, solar, wind) represent 0.10% of primary energy supply for the year 2011 (see Fig.3) [116].

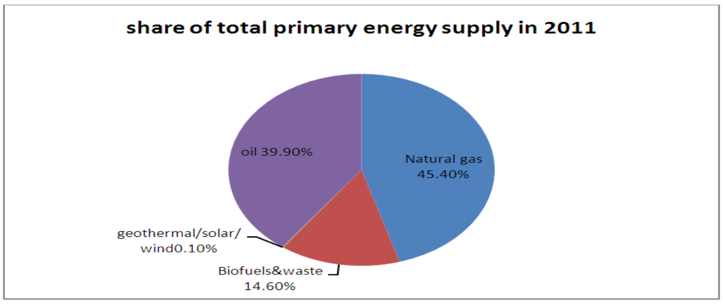

Fig.3. Share of total primary energy supply in Tunisia (2011)

Source: data collected from Ref [116]

The continuous rise of fossil fuels prices and domestic energy consumption with the stagnation of local production have caused many negative economic repercussions. In fact, we assist to a massive outflow of foreign currency and an increase of public spending (fossil fuels are subsidized by the government).
It is therefore necessary that Tunisia implement an energy strategy that can meet the continuous growth of primary energy consumption, especially in the current context of the leap in oil prices. Faced with this situation, the use of renewable energy appears

as an essential option. Since sun is an abundant source in Tunisia, solar thermal can be proposed as a solution to lower the country dependency from imported fossil fuel sources and to contribute to environment protection.

3.2. Engagement to reduce GHG emissions

The key position of Tunisia between the tempered regions of the Northern Hemisphere and the inter-tropical regions makes it a country particularly vulnerable to climate change. Thus, the north of Tunisia benefits from a Mediterranean climate, the center as well as the gulf of Gabes have a semi-arid climate and the rest of the country witnesses a desert arid climate [118].

Tunisia has committed to participating to the mitigation of climate change. In fact, the Tunisian government has signed and ratified all the related international treaties and protocols. Thus, the United Nations Convention on Climate Change, adopted in 1992, was ratified by Tunisia in July 1993. The Kyoto Protocol was also ratified in January 2003.

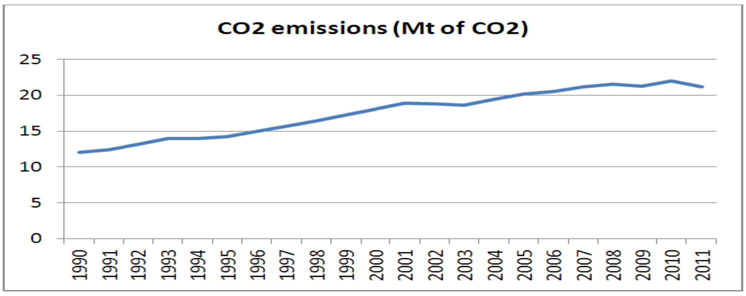

Fig.4. CO2 emissions from fuel combustion in Tunisia
Source: data collected from Ref [116]

The main cause of CO2 emissions in Tunisia is fuel combustion. As shown in Fig.4, those emissions were just 12.08 Mt of CO2 in 1990 and reached 21.13 Mt of CO2 by 2011. So the CO2 emissions are increasing continuously [116].

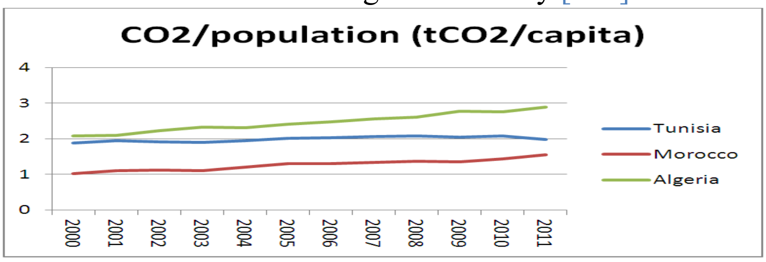

Fig.5. Evolution of CO2 energy related emissions per capita between 2000 and 2011
Source: data collected from Ref [116]

Concerning CO2 emissions per capita (Fig.5), we notice a stagnation of the evolution of CO2 energy related emissions per capita between 2000 and 2011. In fact, those emissions vary around 2 TCO2 per capita (1.88 TCO2 in 2000 and 1.98 TCO2 in 2011) [116]. Comparing Tunisia with its neighbors Algeria and Morocco, we note that in the other two countries the evolution is rather on the increase.

3.3. Great potential of solar energy

Tunisia has the advantage of being exposed to more than 3,000 sunshine hours per year. The following figure presents a general outlook of Global Horizontal Irradiance (GHI) in Tunisia. As shown in Fig.6, the GHI in Tunisia is ranging from 1,700 kWh/m^2 per year in the Center of the country and surpasses 2,000 kWh/m^2 per year in the South. So the highest values are located in the southern regions and also in some highlands.

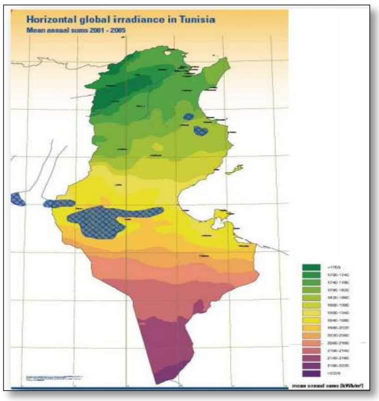

Fig.6.GHI in Tunisia.
Source: Ref. [119]

The solar energy is considered as a promising source in the improvement of the energy balance and the protection of the environment. In fact, it is clear that Tunisia is endowed with good solar energy potentials.

3.4. Favorable regulation to promote RE

Tunisia is the most advanced country in North Africa in terms of institutional and regulatory instruments for the promotion of RE. In fact, since the early 1980s, Tunisia has put in place an evolving regulatory and institutional framework for energy efficiency and RE promotion (for example Law n° 85-48 related to the promotion of RE and Law n° 85-8 related to energy saving).

The National Agency for Energy Conservation (ANME: Agence Nationale pour la Maîtrise de l'Energie) is the leader in the institutional organization of the energy conservation in Tunisia. It was established in 1985 and it is a non administrative public entity belonging under the authority of the Ministry of Industry. The mission of ANME consists in implementing the national policy in the field of energy conservation.

The main Laws and Decrees governing energy conservation and RE in Tunisia are:

-Law n°2004-72 of 2nd August 2004 concerning energy conservation amended by Law n°2009-7 of 9th February 2009. This Law includes important elements in the field of production, transmission and sale of electricity generated from RE.

-Law n°2005-82 of 15th August 2005 establishing a strategy of energy conservation. This strategy includes energy efficiency, RE promotion and energy substitution.

-Law n° 2005-106 of 19th December 2005, this Law stipulates the creation of national fund for energy conservation. This found was created in order to finance actions in the field of energy efficiency and RE promotion.

-Decree n°2005-2234 of 22 August 2005 amended by Decree n° 2009-362. This decree is fixing rates and premium amounts concerning actions covered by the energy conservation plan.

-Decree n°2009-2773 of 28th September fixing conditions of transmission of electricity from RE and also those related to the sale of surpluses of electricity to STEG (Société Tunisienne de l'Electricité et du Gaz).

4. Method: case study of the PROSOL Project

Given this favorable conditions enjoyed by Tunisia, the technology of SWH has always been the best known and the most used RE technology since 1980. However, its development was hindered by the lack of competitiveness compared to conventional systems (mainly natural gas and Liquefied Petroleum Gas: LPG). In this context, the Tunisian government has continued for more than 25 years to launch ambitious plans in order to develop the SWH market. But all these plans have failed to achieve the fixed goals and to use efficiently the huge potential of solar energy. The year 2005 was an important year which was marked by a real change of scale in the SWH market due to the launch of the PROSOL project.
In this section the history of the SWH market in Tunisia is reported, as well as the structure of the PROSOL project and its main mechanisms.

4.1. Main features of the PROSOL project

Given the potential advantages of solar energy, Tunisia has implemented since the early eighties some plans and programs in order to promote the market of SWH (see Fig.7).

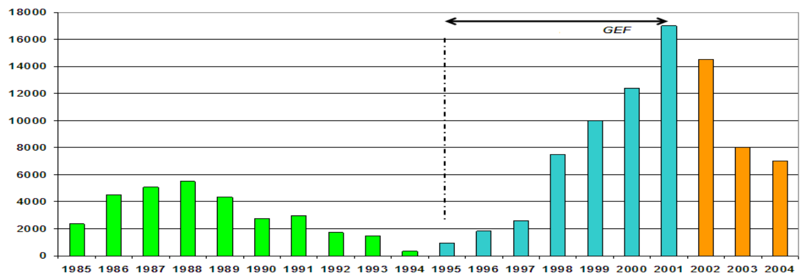

Fig.7. m^2 of installed SWH (1985-2004)

Source: Ref. [120]

Between 1985 and 1994, the government decided that all installed SWHs have to be manufactured locally by the unique public manufacturer called SERPET. The customer receives a loan over a seven-year term in order to buy the SWH with possibility to repay through electricity bills. This period was marked by many technical problems in SWHs manufactured locally therefore the market declined rapidly.

In 1995, the government launched the Global Environment Facility (GEF) project. The main feature of this project was a subsidy of 35% of the cost of SWH financed by the GEF. During the period 1995-2001, the market has progressed rapidly. The GEF project was interrupted in 2001 because of the exhaustion of the funds designed to finance the subsidies. Since 2001, the spread of SWH has largely declined from about 17,000 m² in 2001 to about 7,500 m² in 2004, especially with the absence of an alternative strategy.

Thus, the Tunisian experience shows clearly that SWH market development needs continuous support from the government in order to reach lasting results.
PROSOL was developed in 2005 in order to revitalize the declining Tunisian SWH market which has been recorded since the end of the GEF project in 2001. The PROSOL project was launched by the Tunisian Minister for Industry, Energy and Small and Medium Enterprises and the ANME, with the support of the United Nations Environment Programme (UNEP), the Mediterranean Renewable Energy Center (MEDREC) and the Italian Ministry for Environment and Territory.

The PROSOL project has quantitative and qualitative targets. Quantitatively, it aims for the installation of 222,000 m^2 of solar collectors during the period 2005-2011 in order to redress the downward trend of the market Qualitatively, this program aims for the establishment of sustainable financing mechanisms in the sector of the SWH, better involvements of banks in this market and the establishment of a quality charter.

4.2. Institutional mechanisms

The PROSOL scheme contains the following steps (as described in Fig.8):
-The decision of a customer to buy a SWH from an eligible supplier (who is accredited by ANME).
-The supplier submits a loan application to a participating Tunisian Bank in the project PROSOL.
-Once the bank approves the loan, the installation of the SWH takes place and the customer pays only the administrative costs.
-After the installation, the supplier receives the subsidy payment from ANME and also a payment from the bank.
-The customer repays the loan over a five-year term, through the state electricity utility (STEG) electricity bills.

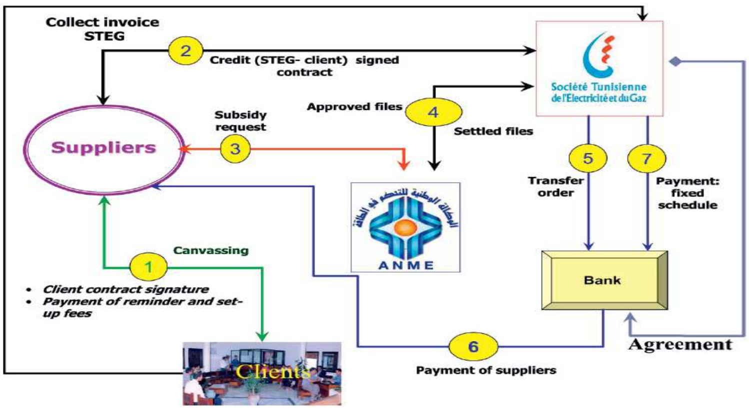

Fig.8. SWH simplified procedures
Source: Ref. [120]

The PROSOL consists of an innovative institutional framework through the strong support of the STEG and the involvement of the banking sector. These actors have played with ANME an important role in the implementation of the project.

- ANME is the project leader and responsible for the implementation and execution of the PROSOL project through a specific unit programme.

- STEG provides loan recovery via electricity bills. So STEG is considered as a refunding guarantor of credits through its electricity bill. As consequence to this guarantee, banks extend the loan terms and lower the interest rates.
- Commercial Banks provide loans to customers, pay suppliers on a fixed schedule and recover credits by STEG.

4.3. Financial mechanisms

The main features of the PROSOL financing scheme are:

- A subsidy of 20% of the cost of SWH, served by the national fund for energy conservation with a ceiling of 200 dinars/m^2.
- A credit from commercial banks in order to finance the cost of the SWH. This credit is granted over a period of 5 years and recovered through STEG bill.

This mechanism has the advantage of being simple and viable. The administrative part is fully supported by the supplier. The customer does not need to pay money and wait subsidies.

Launched in April 2005, the PROSOL project has achieved an immediate success. In order to keep this success over time, some issues of PROSOL were assessed and a new mechanism called "PROSOL II" started in 2007.
The new financial mechanism of PROSOL II covers four essential topics:
-A subsidy of 20% of the cost of SWH, served by the National Fund of energy with a maximum of 100 Dinars/m^2
-A complementary subsidy of about 80 Dinars of the cost of a SWH of 300 liters, served by the Italian Ministry for the Environment and Territory through the MEDREC Funds.
-A costumer's cash participation to the SWH cost of about 10%.

5. Results: achievements and impacts of the PROSOL project on sustainability

In this section we will focus on the achievements in the SWH market made since 2005 and the impacts of those achievements on environmental and socio-economic sustainability.

5.1. Achievements

Due to PROSOL project, the installed surface of SWHs (see Fig.9) had jumped from 7,000 m^2 in 2004 to 22,000 m^2 in 2005. It reached 80, 000 m^2 in 2010. The total surface installed between 2005 and 2010 was 362,842 m^2 [121]. So the average annual growth rate, in terms of m^2 installed, between 2005 and 2010 is about 30% which is very satisfying.

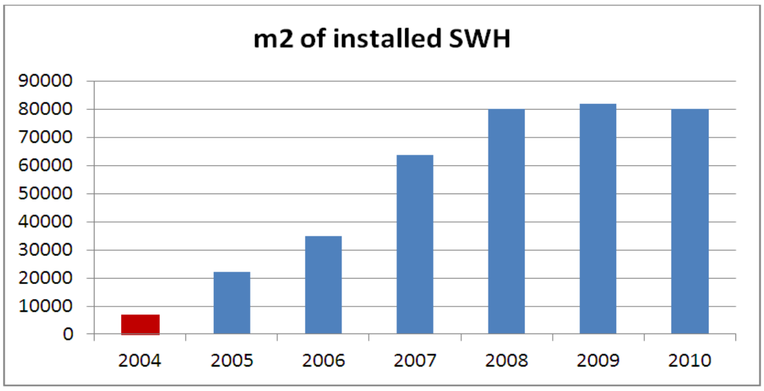

Fig.9. SWH achievement evolution

Source: data collected from Ref [121]

Concerning the number of SWH installed, it increased from 7,300 units in 2005 to 31,500 in 2010 [121].

5.2. Assessment of environmental and socioeconomic impacts

Because of the lack of data we will mention briefly the energy and environmental impacts and we will focus on the socioeconomic impacts mainly the employment creation.

5.2.1. Energy and environmental impacts

According to Baccouche [122], the annual energy savings resulted in the use of SWHs in place of LPG water heaters were only 9 Ktoe in 2004 (before the PROSOL project). In 2010, the annual energy savings reached 34 Ktoe and they will be 70 Ktoe by 2016. Concerning the avoided CO2 emissions linked to the SWHs market. They were just 24 $KTCO_2$ in 2004. In 2010, those emissions reached 90 $KTCO_2$ and they will be 185 $KTCO_2$ by 2016 (see table 1).

Table1.The assessment of energy savings and avoided CO2 emissions

Year	2004	2010	2016
Energy saving (Ktoe/y)	9	34	70
Avoided emissions ($KTCO_2$/y)	24	90	185

Source: data collected from Ref. [122]

5.2.2. Economic impacts

Since the beginning of the PROSOL project, the evolution of SWH market and industry has been very satisfying. In fact, we have witnessed a great growth in the market and local industry of SWH. According to Baccouche [122], due to the PROSOL project, the local industry is composed now of 45 eligible suppliers containing eight local manufacturers, 1100 authorized installers and 206 models of SWH systems and/or collectors, whereas before the beginning of PROSOL the local industry of SWHs contains just one manufacturer and 200 installers.

The growth of SWH market is accompanied mainly by a development of a local industry (see Fig.10). In fact, there are eight factories which produce 70% of all installed SWHs [122]. So, just 30% of all installed SWHs are imported (mainly from Germany, Greece, Turkey and China).

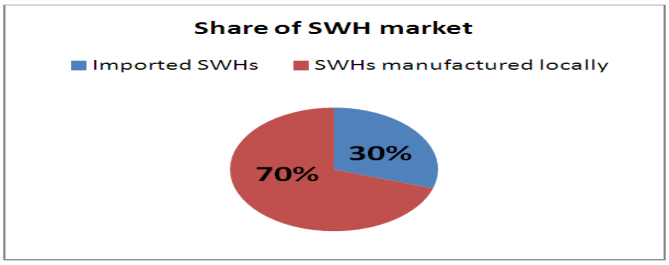

Fig.10. Share of SWH market
Source: data collected from Ref [122]

The development of the local industry is not the only advantage of the PROSOL. In fact the banking sector has also benefiting from this project through the creation of a large market of high quality credit (the repayment is certain through the electricity bill).

The development of the solar thermal industry has required an investment of 175.3 Millions of dinars between 2005 and 2010. In the same period, the amount of subsidies spent is about 31.65 Millions of dinars [120].

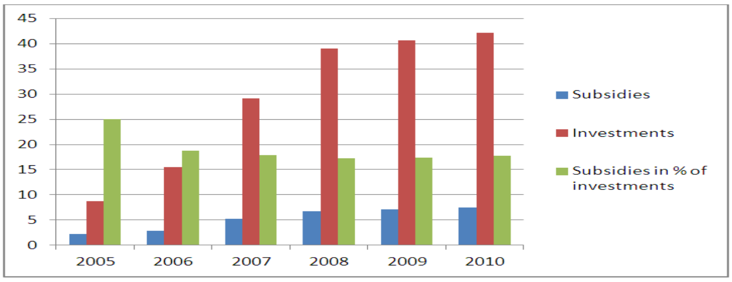

Fig.11. Investments and subsidies in Millions of dinars for the PROSOL project

Source: Ref.[120]

The Fig.11 shows a strong increase in subsidies of around 27% per year but a small reduction in their share of investments over the last 5 years. It should be noted that the subsidies accorded by the government do not give rise to an additional public spending because they are largely compensated by the avoided subsidies which were dedicated to LPG heaters.
PROSOL has also positive impacts on the value of exports in this sector. In fact, the value of exports had increased from 25,334 TND in 2006 to 495,917 TND in 2010 [120]. The following figure shows a significant acceleration in exports from 2009.The SWHs are exported mainly to the North African countries: Morocco, Libya and Algeria.

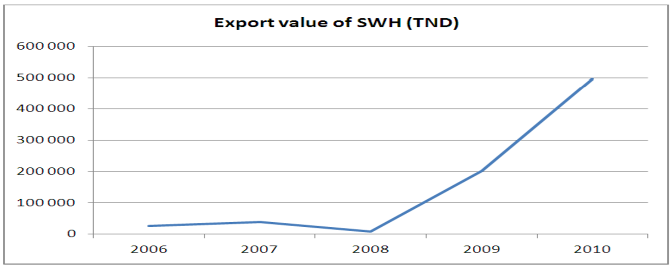

Fig.12. Export value of SWH
Source: data collected from Ref [120]

5.2.3. Social impacts

Thanks to PROSOL project, the market has fully recovered and it reaches record levels. This recovery encourages the creation of new industrial operators and the development of networks of installers. The solar energy sector has created a significant dynamic in the labor market during the last decade. In fact, PROSOL project has contributed to the creation of new jobs: 45 suppliers and approximately 1100 companies specialized in the installation of SWH are involved in this project. The number of jobs created is around 3,000 jobs [122].

Thus, the PROSOL project has created many new jobs for project design, installation, maintenance and commercial functions. The jobs created are, mostly, local jobs and they can generate income and improve living conditions of many families. In fact, geographical breakdown of installers in 2010, as shown in the table below, is quite satisfactory. Thus there is no concentration of most of installers in the North of the country.

Table2: The regional distribution of installers

Area	Number of companies specialized in the installation
Great Tunis Region	285
North East	149
North West	88
Central East (including Sfax)	362
Central west	77
South East	96
South West	43
Total	1100

Source: Ref.[120]

Among the positive social impacts we can also mention the improvement of the quality of hot water service and its accessibility to all social layers. In fact, with the advantageous payment terms in PROSOL project, even the poor class can access to this service which is relatively expensive around 1,400 TND.
According to a study concerning customer satisfaction, conducted by a specialized office, 87% of the customers are favorably impressed with the use of SWH.

6. Discussions

Although the PROSOL project has realized a great success, it contains several shortcomings that need to be eliminated in the coming years.

-First, Targets are setting generally without taking into account the specificity of each region in Tunisia. So it would be much better to develop some sub-strategies and targets for each region.

-Secondly, it should be noted that there are deficiencies in the financial means implemented by the government in order to support the PROSOL project.

- The relatively low level of subsidies that do not exceed 20% of the cost of the investment and that in comparison with other Mediterranean countries where the support of the government to renewable energy is stronger.
- The installation service is not exempted from value added tax.
- Payment of customs duties on imported components for the local manufacture of SWHs.
- The absence of bonus interest rates from the bank as is the case in several countries in Southern Europe.
- The lack of specific support neither financial nor fiscal to the local manufacturing industry of SWHs.
- The absence of policies to control prices of SWHs.

Finally, deficiencies are also noted in the institutional and organizational levels including:

- The insufficiency of logistical and human resources to provide effective control and maintenance to installed equipments.
- The absence of communication with customers regarding the steps to follow in case of problems.
- The lack of clear procedures for suspension of subsidy in case of non-compliance from suppliers.
- The efforts made by ANME in the field of communication and awareness are insufficient.
- The need of more coordination between regional structures of the ANME.

7. Conclusions

The growing consumption of energy has caused serious damages to the planet. It is therefore necessary to use RE in order to protect our environment and follow the path of sustainable development. Tunisia is a net importer of energy with a huge potential of solar energy. That's why Tunisia has accorded a great importance to the promotion of the solar energy through PROSOL project. This project has been a change of scale in the solar thermal market since 2005. Indeed, the installed surface of SWHs had jumped from 7,000 m^2 in 2004 to 22,000 m^2 in 2005. It reached 80, 000 m^2 in 2010. This project has contributed to the reduction of GHG, the creation of new jobs (around 3,000 jobs), the development of a local industry and also to the increase of exports value in this sector. Given the success of residential PROSOL, it was widened to the tertiary and industry sectors with the adding of new institutional and financial mechanisms.

But we must note that efforts are insufficient and that the solar market faces several obstacles. In fact, the Tunisian experience is far from the successful experiences of other countries such as Germany, Spain and Denmark. Tunisia has all the necessary conditions; a great potential of RE, a very qualified labor but the government support and the institutional and regulatory instruments still insufficient.

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